Evaluation of NASA Data Products for RPO Applications

Troy Frisbie (NASA), Dr. Kelly Knowlton (SSAI), Dr. Jane Andrews (SSAI)

NASA, John C. Stennis Space Center

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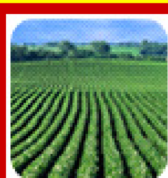
John C. Stennis Space Center, Mississippi

(Troy Frisbie, Air Quality Project Manager)

- Stennis Space Center (SSC) is one of ten NASA field centers
- Two lines of business: Rocket Propulsion and Applied Sciences
- The Applied Sciences Directorate (ASD) is responsible for evaluating and benchmarking NASA products for partner agencies to develop, support and enhance Decision Support Systems (DSSs)
- ASD Mission: "To optimize benefits from NASA's Earth Science investments, through Systems Engineering, to advance DSSs that serve the Nation."
- Remote Sensing: an ASD legacy
  - NASA's Commercial Remote Sensing Program (CRSP)
  - MODIS ground station and downlink capabilities
  - Scientific Data Purchase (SDP)
  - Joint Agency for Commercial Imagery Evaluation (JACIE)

Applied Sciences Directorate - Stennis Space Center

ASD supports all 12 national applications including "Air Quality", and work with other Space Centers to explore new ideas.



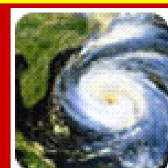
Agricultural Efficiency

Air Quality

Aviation

Carbon Management

Coastal Management

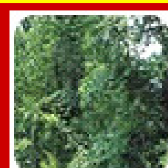


Disaster Management

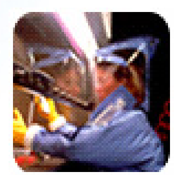
Ecological Forecasting

Energy Management

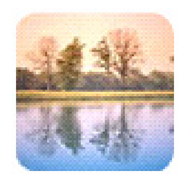
Homeland Security



Invasive Species



Public Health



Water Management

SSC is the Lead Center

Preliminary Investigation – Phase I

- **In FY 2004, NASA HQ commissioned SSC ASD to study air quality strategic plans and initiatives within the federal agencies**

- **Final Draft Made Public February 2005:**

  "Air Quality: Decision Support Tools, Partner Plans, Working Groups, Committees"

  - ✓ *Twelve agencies contacted*
  - ✓ *Nine agencies had official air quality programs*
  - ✓ *Shared Concerns: The environment, technology development, the need for partnerships with other federal agencies*
  - ✓ *Available Resources*
  - ✓ *EPA Regional Planning Organizations (RPOs) were one of the highest ranking for potential collaboration with NASA*

Report of Findings and Recommendations

- Why EPA – Regional Planning Organizations?
  - ✓Have a need for more air quality monitoring
  - ✓Need quantification for Interstate transport of haze
  - ✓Would like to address modeling inaccuracies
  - ✓Currently some capability for accepting NASA satellite data (FASTNET)
  - ✓Clearly defined goals and strategies
  - ✓Some resources available

Current Actives - Phase II

(Dr. Jane C. Andrews)

<u>Purpose:</u> **To investigate how NASA's Earth Science data products could be used for RPO applications when integrated with VIEWS and/or FASTNET**

- **<u>Time Frame:</u>** **Complete by September 30, 2005**

- **<u>Motivation</u>:** **The Integrated Budget Performance Document (IBPD), metrics for FY05; "To Benchmark a National Application, specifically Air Quality"; 5ESA2.1; 5ESA10.1**

Approach

- Determine the level of RPO interest
- Determine RPO data requirements
  - ✓ Applications
  - ✓ Specifications
- Identify NASA satellite data products that satisfy RPO requirements
- Document VIEWS/FASTNET capabilities and operations
  - ✓ Initial focus will be on FASTNET, with longer-term goal of providing refined data products to VIEWS
- Prepare Report of Findings
- Make Recommendations

Progress Report

- Conducted conference calls with RPOs and affiliated personnel
- Initial teleconference: *February 22, 2005*
- Subsequent teleconferences: *March 16; April 19; May 9, 2005*
- Maintained continuous dialog and exchange of ideas, questions and answers
- Conducted an extensive literature search and review
  - ✓NASA sensors
  - ✓FASTNET
  - ✓Publications related to integration of satellite data

Progress Continued

- RPO <u>Applications</u> Defined
  - ✓ PM 2.5 including dust and smoke (ug/m^3)
  - ✓ PM 10 including dust (ug/m3)
  - ✓ Nitrogen Oxides and Sulfur Oxides if possible

Progress Continued

- **RPO Specifications Defined**
  - ✓ **Daily flyover time**
  - ✓ **Near Real Time data availability**
  - ✓ **Horizontal Resolution: 10 – 40 km**
  - ✓ **Vertical Resolution: Surface and total column (derived if necessary).**
  - ✓ **Imagery:**
    - i. **Images**
    - ii. **Numerical data**

Progress Continued

- **Currently working to identify RPO specifications for future FASTNET inputs and outputs**

Desired Inputs

- ✓ Categorical list of monitoring sites
- ✓ Images
- ✓ Numerical data
- ✓ GIS coordinates
- ✓ Weblinks

Progress Continued

- **FASTNET Data Base (continued)**

<u>Desired Outputs</u>

- ✓ Images
- ✓ Numerical data – from satellite imagery
- ✓ Estimate of uncertainty
- ✓ Sun angle
- ✓ Ground conditions
- ✓ Cloud or other potential interference
- ✓ Non-detect code or flag, i.e., cloud masks
- ✓ Model inputs

Satellite Imagery

(Dr. Kelly Knowlton)

Currently identifying satellite datasets for RPO applications and specifications

Moderate Resolution Imaging Spectroradiometer (MODIS)

VITAL FACTS:

PRODUCT SUMMARY: Tracking of aerosols including particle size, dust, smoke and ozone.

- Instrument: Whiskbroom imaging radiometer
- Spectral Bands: 36 from 0.4 to 14.5 µm (visible and infrared)
- Spatial Resolution: 0.25 km, 0.50 km, and 1 km
- Repeat Time: Global coverage in 1-2 days (up to 2X/day)
- Design Life: 6 years
- Forty-four standard MODIS products
- Aerosol (MOD04) and Cloud (MOD06) Products identified

MISSIONS:

- Terra – Dec. 1999
- Aqua – May 2002

OWNER:

- U.S., NASA

FOLLOW-ON:

- VIIRS – NPOESS

NASA Satellite Data Products

MOD 04: Aerosol Product

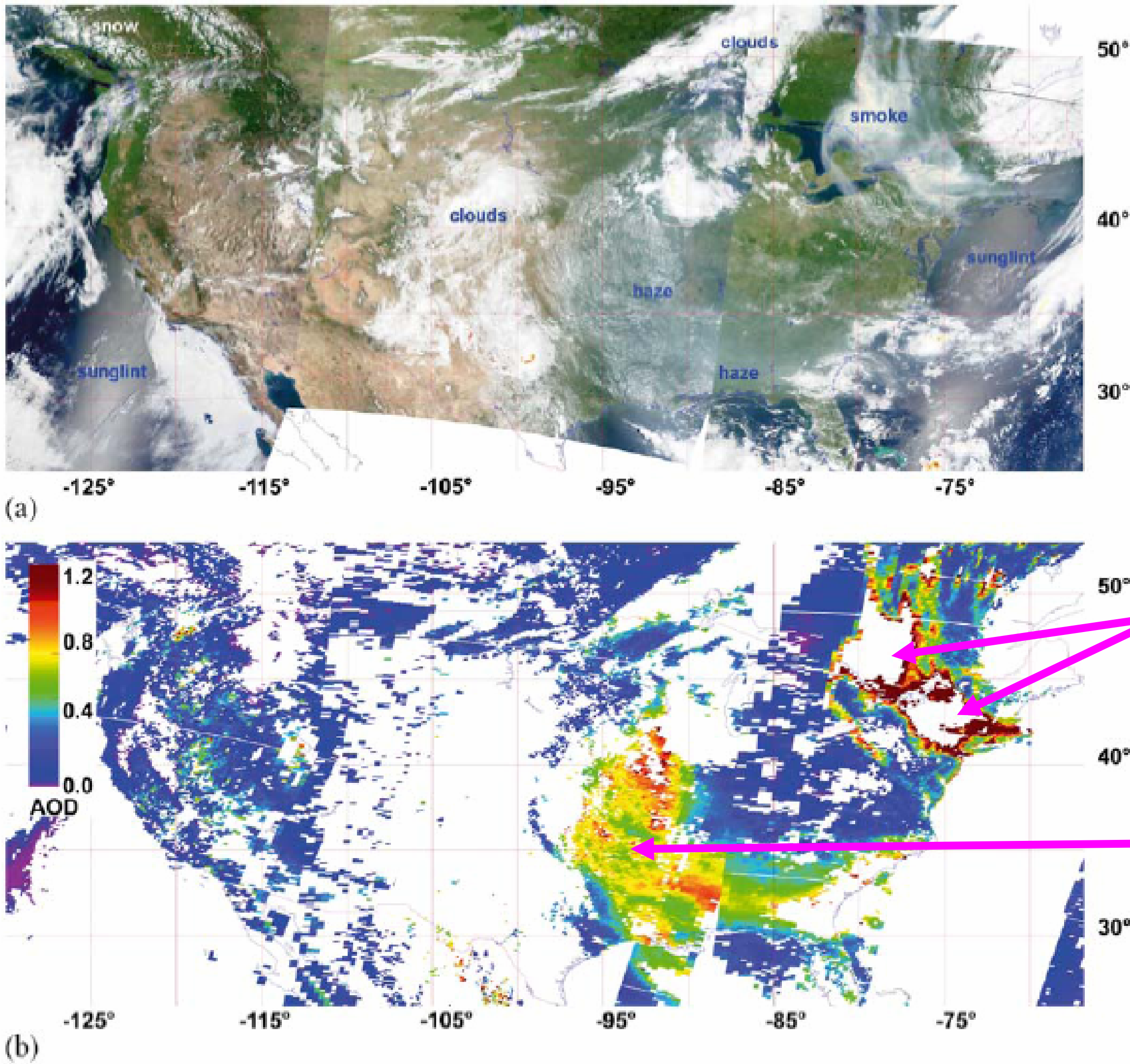
Product Spatial -Temporal Characteristics		
Time Interval	Grid Resolution	Processing Level
1- 2 day repeat	10 km	2

MOD 06: Cloud Product

Product Spatial-Temporal Characteristics		
Time Interval	Grid Resolution	Processing Level
1 – 2 day repeat	1 km (cloud optical parameters and cirrus detection)	2
1 – 2 day repeat	5 km (cloud top parameters)	2

MODIS Visible Image and Corresponding Aerosol Optical Depth (AOD)

J.A. Engel-Cox et al. / Atmospheric Environment 38 (2004) 2495-2509



MODIS Data, 6 July 2002. (Upper) Level 1b RGB composite image; (Lower) Level 2 AOD.

MODIS "Visible" composite & AOD estimate for 7/6/02

MODIS AOD Algorithm initially filtered out the densest Quebec smoke, but nicely captured the sulfate haze, displaced slightly to the SW of its "usual" location

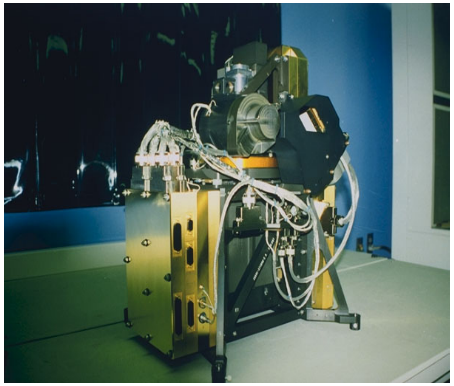
Credit: Rich Poirot, Vermont Agency of Natural Resources, MANE-VU RPO

TOMS
(Total Ozone Mapping Spectrometer)

VITAL FACTS:

PRODUCT SUMMARY: Measurements of aerosol particulates, sulfur dioxide, and ozone. Does not differentiate between dust and smoke.

- Instrument: Backscatter UV spectrometer
- Spectral Bands: Six from 0.3086 to 0.360 µm (UV)
- Horizontal Resolution: 40 x 40 km at nadir
- Vertical Resolution: ~5 km
- Vertical Profile: 0-58 km
- Repeat Time: Daily global coverage
- Design Life: 2 years (exceeded)



OWNER:
- U.S., NASA

HERITAGE:
- SBUV

FOLLOW-ON:
- OMI
- Aura mission -June 2004

Ozone Monitoring Instrument (OMI)

VITAL FACTS:

MISSION:

- Aura – June 2004

OWNERS:

- Netherlands, NIVR
- Finland, FMI
- U.S, NASA

HERITAGE:

- TOMS
- GOME
- SBUV

PRODUCT SUMMARY: Detects dust, smoke, nitrogen oxides, sulfur oxides and ozone on a daily or bi-daily basis; Reduced interference by clouds.

- Instrument: Hyperspectral pushbroom imager
- Spectral Bands: 740 over 0.270-0.314 µm, 0.306-0.380 µm, 0.350-0.500 µm (UV and visible)
- Horizontal Resolution: 13 x 24 km (nominal), 13 x 13 km (zoom), and 36 x 48 km (ozone profiles)
- Vertical Resolution: 6 km (ozone profiles)
- Repeat Time: Daily global coverage
- Design Life: 5 years

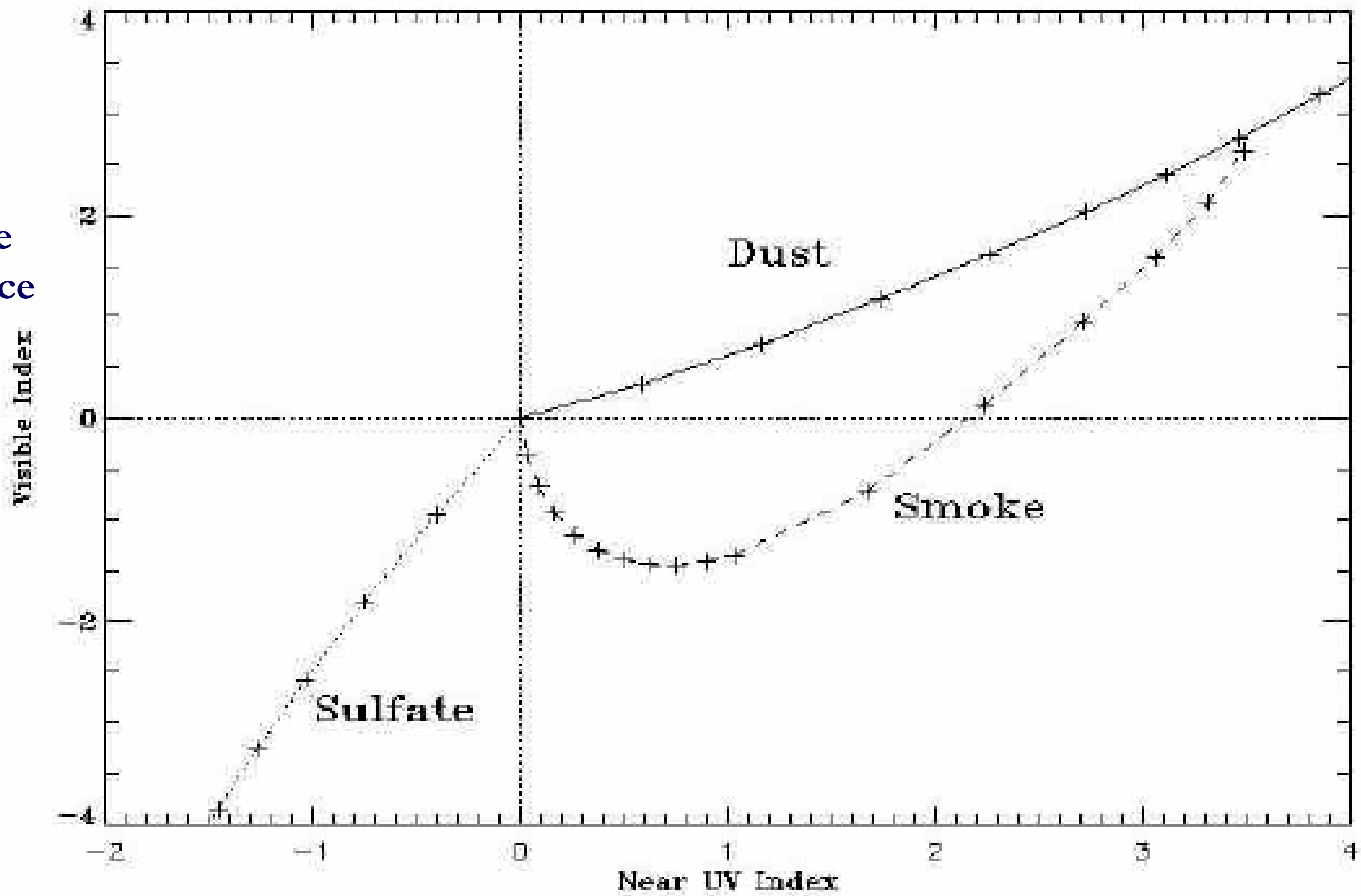
FOLLOW-ON:

•NPP OMPS

OMI Separation of Aerosol Types using Aerosol Indices

<u>Aerosol Index</u>

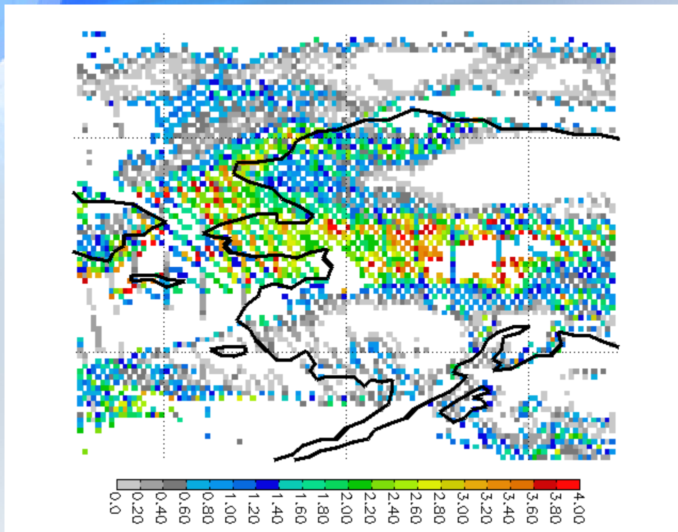
- Is derived from the ratio of two radiance measurements
- Dependent on absorption & reflection



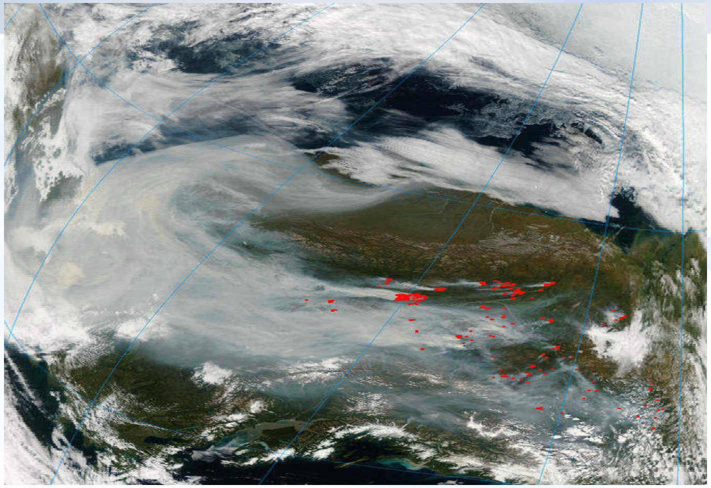
- Near UV Index (342.5 and 388.0 nm) - permits separation of non-absorbing aerosols (sulfates) from absorbing aerosols (dust, smoke)
- Visible Index (388.0 and 494.5 nm) - permits separation of dust from smoke (provided smoke aerosol optical thickness is less than 2)

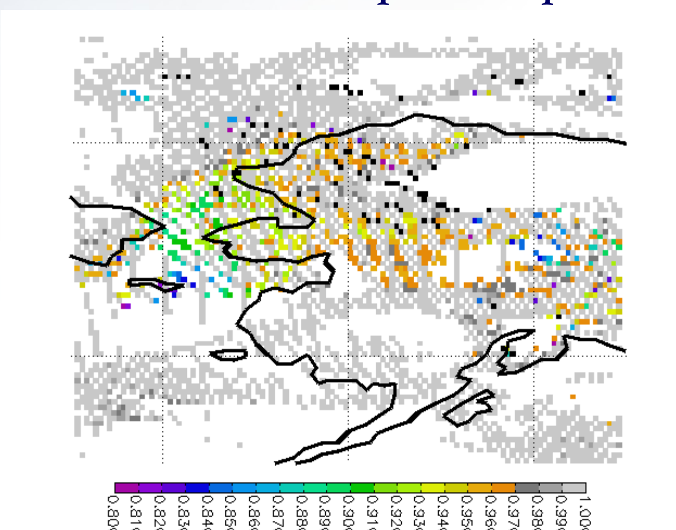
P. Stammes and R. Noordhoek, OMI Algorithm Theoretical Basis Document, Vol. III, Version 2.0, 2002.

Dense smoke layer over Alaska on August 21 04

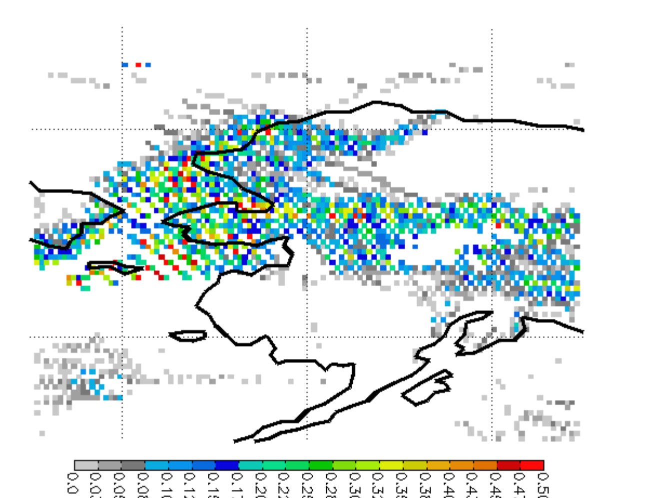


OMI Extinction Optical Depth


Aqua-MODIS RGB image



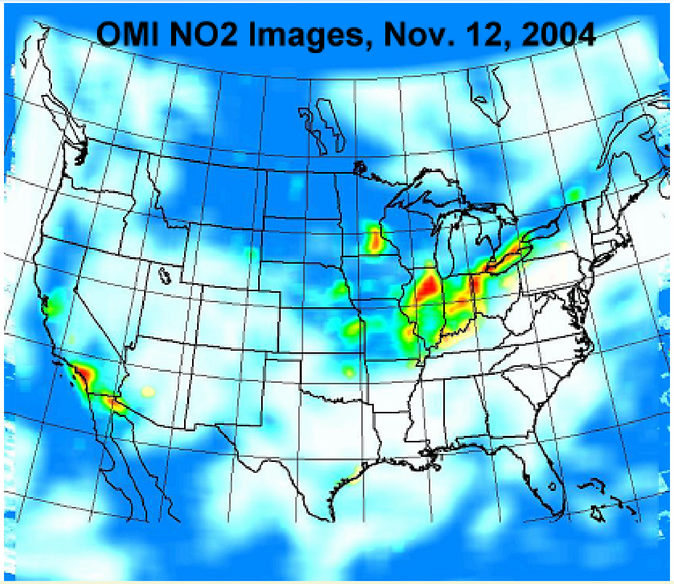
OMI Single Scattering Albedo

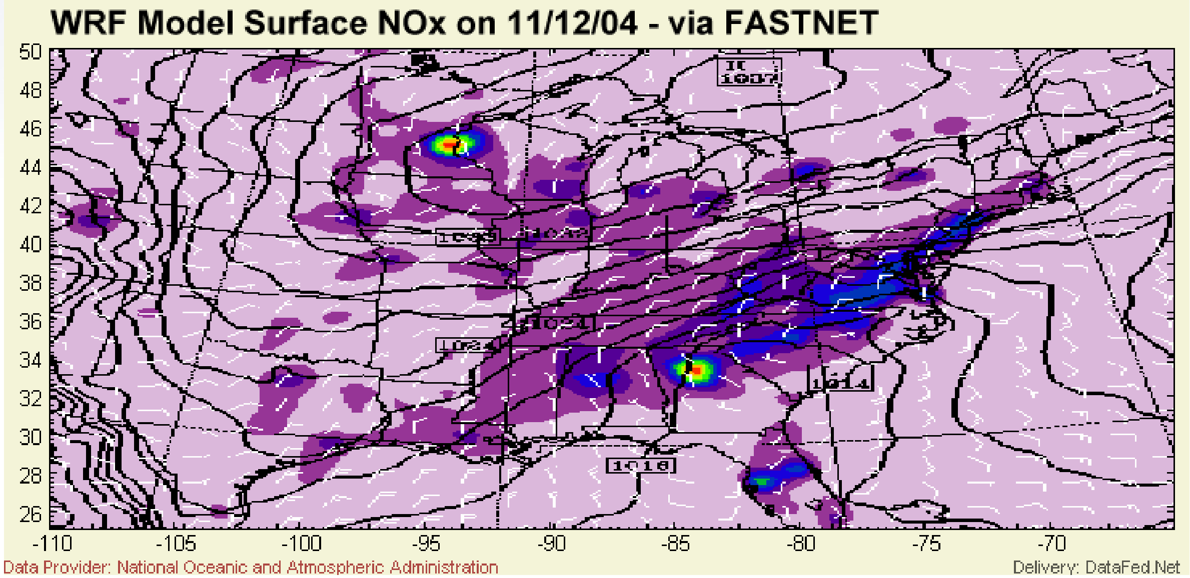


OMI Absorption Optical Depth

Credit: Omar Torres, JCET, University of Maryland, Baltimore County

OMI NO_2 Compared with WRF Model for Surface NO_x





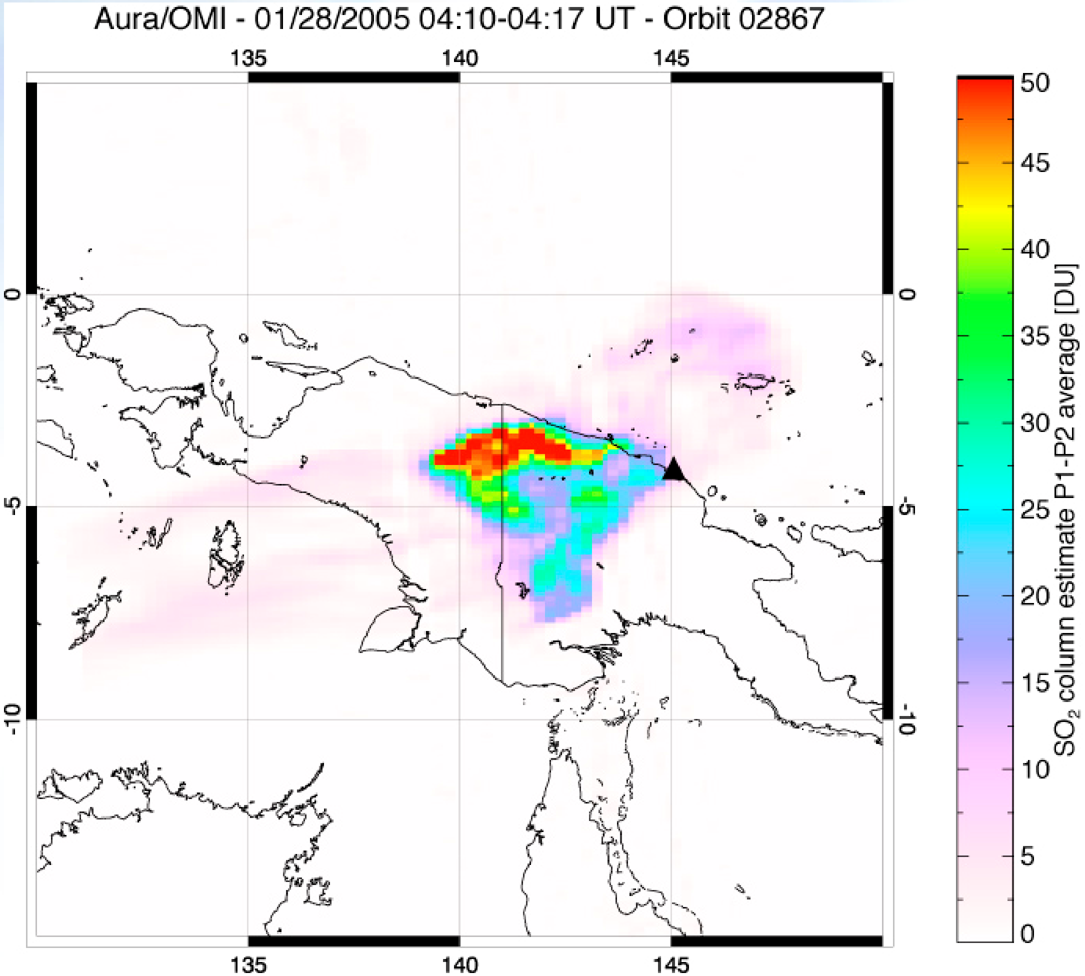
Potential for "real-time" continuous model evaluation?

Note: WRF (& NAAPS) Model results available via FASTNET as images-only

Credit: Rich Poirot, MANE-VU RPO

OMI SO_2 Image: Eruption of the Manam Volcano in New Guinea

"The Manam volcano erupted explosively in the middle of the night on January 27, 2005, sending a cloud of ash and sulfur dioxide over New Guinea. About 12 hours after the eruption, OMI flew over. This image was produced from preliminary, uncalibrated data provided by OMI."



NASA image courtesy of Simon Carn, Joint Center for Earth Systems Technology (JCET), University of Maryland Baltimore County (UMBC)

http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=16820

OMI

- Currently being Validated and Verified by Goddard Space Flight Center (GSFC) Personnel
- Data are still very provisional
- Level 3 gridded ozone data – became available March 27, 2005
- Level 2 data for ozone and reflectance – NOW AVAILABLE through the DACC at GSFC
- Aerosol, NO_x and SO_2 data – possibly available in fall, 2005
- Probably can't detect sharp peak SO_2 plumes but may be able to detect after plume spreads out

Tropospheric Emission Spectrometer
(TES)

VITAL FACTS:

MISSION:

- Aura – June 2004

OWNER:

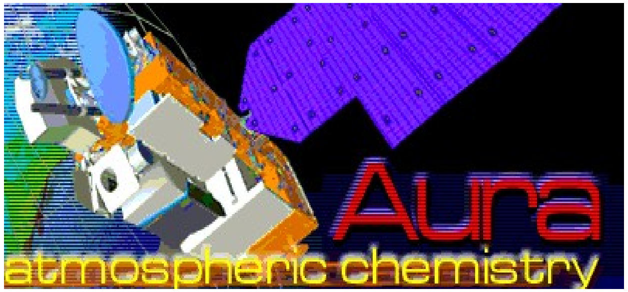
- U.S., NASA

HERITAGE:

- ATMOS
- SCRIBE
- AES

PRODUCT SUMMARY: Direct global measurements of nitrogen oxides, sulfur dioxide, carbon monoxide, methane, and ozone.

- Instrument: High-resolution IR spectrometer
- Bands: Four from 3.2 to 15.4 µm, tunable (infrared)
- Horizontal Resolution: 5.3 x 8.5 km (nadir mode) for O_3, CO, CH_4; 53 x 169 km (limb mode) for O_3, CO, HNO_3, NO_2, CH_4
- Vertical Resolution: 2.3 km (limb mode)
- Vertical Profile: 0-34 km (limb mode)
- Repeat Time: Every 2 days
- Design Life: 3 years

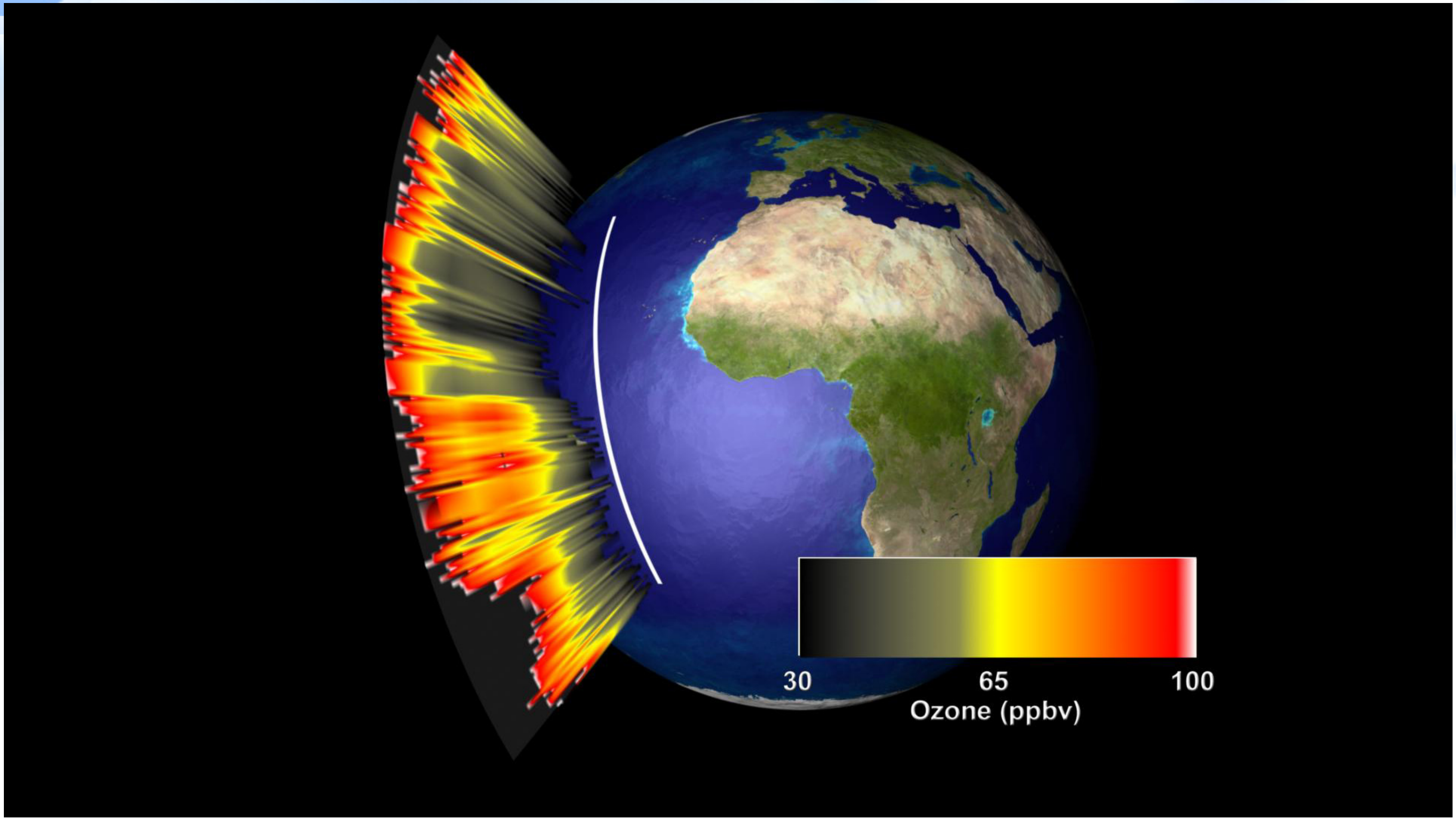


TES

- All TES data and images are provisional at this time
- TES is currently off line but should be back up in a couple of weeks
- TES is capable of detecting surface ozone from 0 – 5 km, 5 -10 km, etc. (higher vertical resolution than OMI)

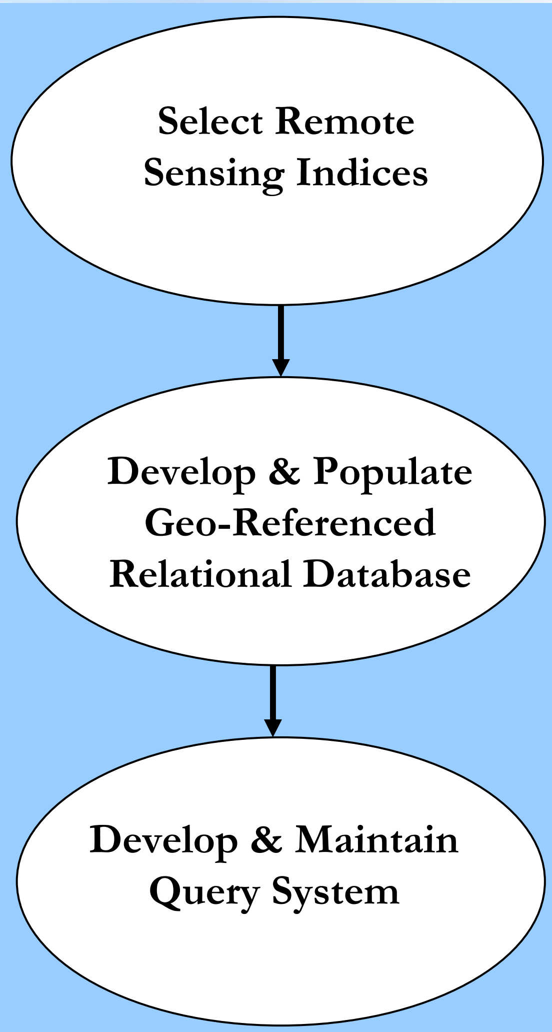
TES Vertical Ozone Profile

Example of what will be available



http://www.nasa.gov/vision/earth/lookingatearth/aura_first3.html

Process to Develop a System to Integrate Satellite Remote Sensing and In Situ Air Quality Data



NASA & RPOs jointly decide which remote sensing air quality indices will be the most useful for comparing to in situ air quality measurements

NASA develops and maintains a geo-referenced relational database with web access that is consistent with the agreed-upon query system.

RPOs develop and maintain the web based query system that accesses the remote sensing and in situ air quality data bases with tools for joint display, summary and analysis

Short Term Benefits to the RPOs

- Apply satellite data to emissions inventories
- Build advanced affordable air quality models
- Increase model accuracy and sensitivity
- Provide rich spatial information to supplement data analysis of local, regional, and intercontinental transport events from manmade and natural source influences

Long Term Benefits to the RPOs

- Link satellite data to atmospheric transport dispersion models, using satellite data to fill in the gaps
- Embed global and regional models
- Model Evaluation – International Tracking Capabilities
- Convert International Models to Air Quality Field Emissions
- Develop historical archive for retrospective event analysis, refining natural background estimates and discerning long-term chronic source influences

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Mark Janssen — *Lake Michigan Air Directors Consortium, Emissions Director, Midwest RPO, Des Plaines, IL*

Tom Moore — *Cooperative Institute for Research in the Atmosphere, Colorado State University, Fort Collins, CO; WRAP RPO*

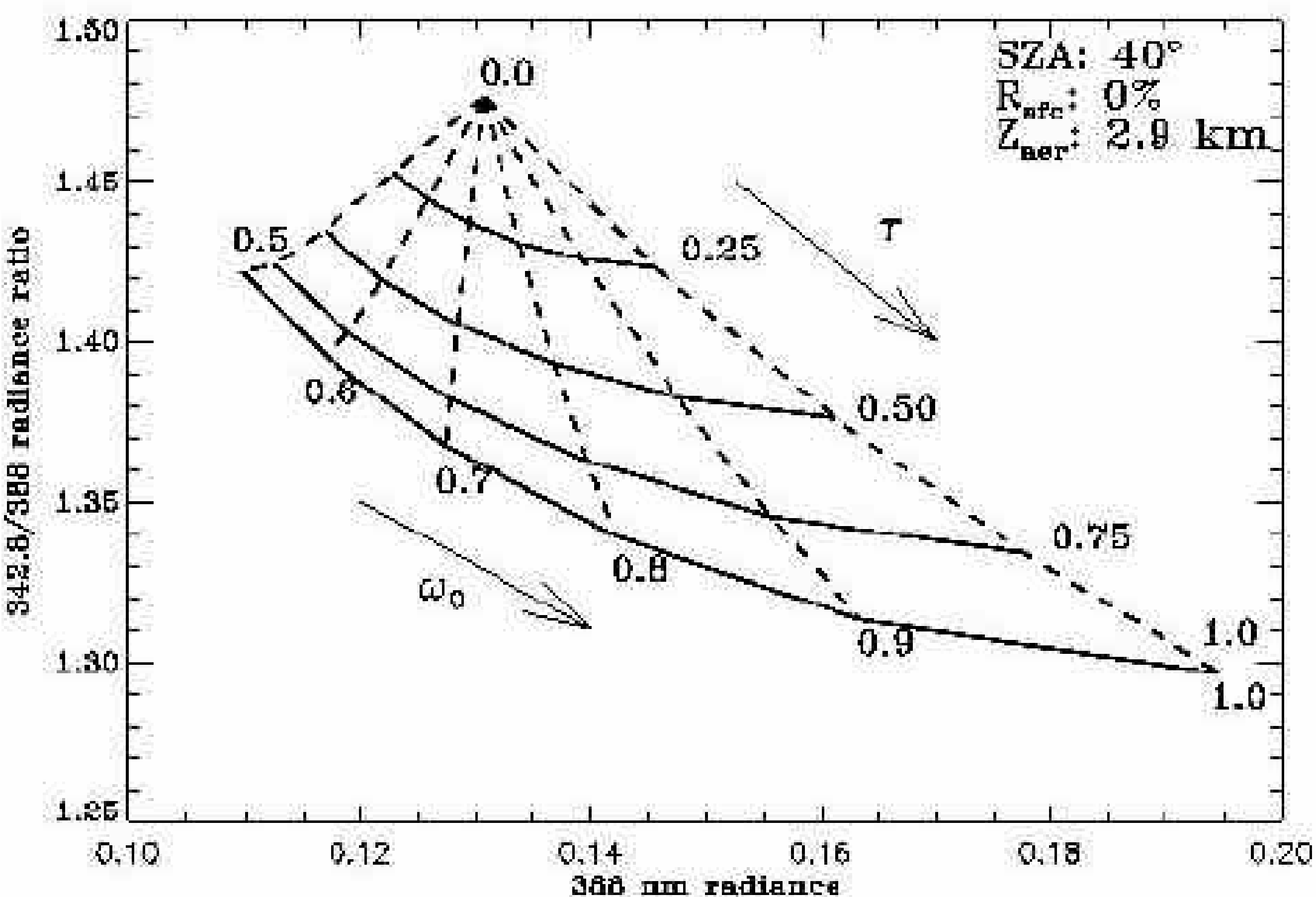
Marc Pitchford — *NOAA – Air Resources Laboratory, Desert Research Institute, Las Vegas, NV; WRAP RPO*

Rich Poirot — *Vermont Agency of Natural Resources, Department of Environmental Conservation, Air Pollution Control Division, Waterbury, VT; MANE-VU RPO*

Dale Quattrochi — *Earth and Planetary Science Branch, NASA, Marshall Space Flight Center, Huntsville, AL*

Questions?

Retrieval of Aerosol Optical Thickness (τ) and Single Scattering Albedo (ω_o) from Aerosol Indices



A determination of τ and ω_o from measured radiance values for a particular atmospheric model; the specific relation of τ and ω_o to radiance values depends on the atmospheric model

P. Stammes and R. Noordhoek, 2002

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Dr. Kelly Knowlton (2)
Dr. Jane Andrews (2)

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Presentation at Air Quality Regional Planning Organizations' National Technical Meeting, Boulder, CO, USA, June 8-10, 2005

14. ABSTRACT
This presentation summarizes preliminary investigations at SSC by NASA's ASD in Air Quality including decision support tools, partner plans, working groups, and committees. An overview of follow-on short-term and long-term objectives is also provided. A table of potential NASA sensors for use with air quality applications is included, along with specifications for MODIS 04 and 06 products. This presentation was originally given by Rich Piorot of the Vermont Department of Environmental Conservation - Air Quality as part of a round-table discussion during "Exploring Collaborative Opportunities in Air Quality Monitoring, Modelling and Communication Workshop" in Boulder, CO, on March 21-22, 2005; verbal consent for this presentation to be provided to Mr. Piorot was given by the NASA SSC ASD Air Quality Program Manager on March 14, 2005.

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